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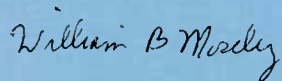
## Digital Terrain Elevation Data Compact Disk-Read Only Memory Prototype Evaluation

by **Jerry L. Landrum and others**  
**James E. Braud**  
**John L. Breckenridge**  
**Susan V. Carter**  
**Mapping, Charting, and Geodesy Division**  
**Ocean Science Directorate**

## Foreword

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This report summarizes the result of the Navy's prototype evaluation of the Defense Mapping Agency's Compact Disk-Read Only Memory as a distribution medium for the Digital Terrain Elevation Data. Twenty individuals participated in the evaluation. They were sent evaluation packages containing data samples and evaluation forms. The CD-ROM proved to be an excellent distribution media that offered large cost savings. The recommendations in this report are being incorporated into the production and will result in a more usable product for the Navy.



**W. B. Moseley**  
Technical Director



**J. B. Tupaz, Captain, USN**  
Commanding Officer

## **Executive Summary**

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This report presents the Navy's evaluation of the Defense Mapping Agency's prototype Digital Terrain Elevation Data (DTED) on Compact Disk-Read Only Memory (CD-ROM). The CD-ROM medium offers large savings in cost and in storage space, and is an appropriate on-line digital data base for mini- and micro-computers. A brief description of the CD-ROM technology is presented along with directions for reading the DTED data. Sample applications and results are described, and the evaluation team's recommendations are presented.

## Acknowledgments

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This work was sponsored by the Oceanographer of the Navy (OP-096), and was supported by Program Element 63704N, Mr. J. Braud, Program Manager. Mr. Jere Cadoret of the DMA Systems Center provided a reader program that was very helpful in getting the sample applications going. We would like to thank Ms. Mary Clawson and Ms. Maria Kalcic of NORDA's Mapping, Charting, and Geodesy Division, Mr. John M. Quinn of the Naval Oceanographic Office, and Mr. Stanley S. Leroy of the Naval Research Laboratory for their reviews and helpful suggestions. Special thanks go to the evaluation team members for their work in rapidly gearing up to evaluate this new technology and for submitting their results promptly.

# Contents

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<b>1.0 Introduction</b>	<b>1</b>
<b>2.0 DTED CD-ROM Overview</b>	<b>1</b>
<b>3.0 Reading the DTED CD-ROM</b>	<b>1</b>
<b>4.0 Evaluation System Description</b>	<b>2</b>
<b>5.0 Sample Applications and Results</b>	<b>2</b>
5.1 Application 1: Subsampling of a CD-ROM Coverage Area to a Disk File	2
5.2 Application 2: Terrain Relief Map of DTED from CD-ROM	2
<b>6.0 Evaluators' Responses to Questionnaire</b>	<b>5</b>
6.1 User Information	5
6.2 Packaging and Security	5
6.3 Maintenance	5
6.4 Ancillary Data	5
6.5 CD-ROM Index	5
<b>7.0 Conclusions</b>	<b>5</b>
<b>8.0 Recommendations</b>	<b>10</b>
8.1 Recommendations Not Affecting the DTED File Format	10
8.2 Recommendations Affecting the DTED File Format	10
<b>9.0 References</b>	<b>11</b>
<b>Appendix A: "C" Program Listings</b>	<b>13</b>
<b>Appendix B: Evaluation Team Members</b>	<b>27</b>
<b>Appendix C: Collated Responses</b>	<b>31</b>
<b>Appendix D: DMAP Questionnaire</b>	<b>39</b>
<b>Appendix E: Evaluation of Digital Terrain Elevation Data (DTED) on CD-ROM Tactical Air Mission Planning System (TAMPS) Application (draft)</b>	<b>41</b>



# Digital Terrain Elevation Data Compact Disk-Read Only Memory Prototype Evaluation

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## 1.0 Introduction

The Mapping, Charting, and Geodesy (MC&G) Division of the Naval Ocean Research and Development Activity (NORDA) is the Navy's lead laboratory for MC&G. The Oceanographer of the Navy tasked NORDA's Digital MC&G Analysis Program (DMAP) to coordinate the Navy's use and development of digital MC&G data.<sup>1</sup> The Commander, Naval Oceanography Command, has tasked DMAP to coordinate the Navy's evaluation of Defense Mapping Agency (DMA) prototype data bases.<sup>2</sup>

Compact Disk-Read Only Memory (CD-ROM) is an excellent medium for the distribution of large data sets, such as the Digital Terrain Elevation Data (DTED). DTED is used or is planned to be used in 45 Navy and Marine systems, which include aircraft mission planning, moving map cockpit displays, targeting, and navigation.<sup>3</sup> CD-ROM allows data organization through directories, subdirectories, and files, while offering either random or sequential access of data within a particular file. In addition to its potential as a distribution medium, it may serve as an on-line data base when speed of access is not a critical issue.

This report describes the CD-ROM technology, DTED file organization and structure, sample applications, responses to the evaluators' questionnaires, and recommendations.

## 2.0 DTED CD-ROM Overview

The CD-ROM technology uses laser optics and became commercially available in 1985. A CD-ROM weighs less than one ounce, and can be mass produced for about \$2.00 per copy. Each CD-ROM holds as much data as about twenty 1600 BPI magnetic tapes. Since magnetic tapes weigh over 2 pounds and cost about \$30.00 to produce and ship, tremendous savings of time, money, and space are obvious. Reader devices with software drivers for microcomputers are available for about \$800.00 or less. Digital Equipment drives may be connected to Micro-VAXs either directly or to other machines via Ethernet Local Area Networks.

Currently there are two known information storage formats for CD-ROMs, the High Sierra de facto

standard and the International Standards Organization (ISO) 9660. The format used is transparent to the user and application program as long as the correct software driver is installed. The prototype DTED CD-ROMs are in the High Sierra format, but DMA plans to use the ISO 9660 format for future distribution.

The proposed organization of the DTED Level 1 data set is shown on DMA's Proposed DTED CD-ROM Index. The worldwide distribution set is to consist of 85 CD-ROMs organized around Operational Navigation Chart (ONC) boundaries. Many of the CD-ROM areas have odd-shaped geographic limits to minimize the number of necessary CD-ROMs and to follow the ONC boundaries.

The DTED directory contains a number of subdirectories that correspond to each one-degree band of longitude. Each of these longitudinal directories contains the one-degree-square DTED files for that longitude band. Thus, a specific geographic coordinate may be used to construct a file specification for the retrieval of the DTED data for that coordinate. The format of the individual one-degree DTED cells is similar to the present magnetic tape distribution format.<sup>4</sup> (The difference is that on the CD-ROM all records are of fixed length, whereas on magnetic tape, records may vary in length, depending on data coverage.) Additionally each CD-ROM contains a gazetteer file to provide geographic positions for selected place names in the covered area.

## 3.0 Reading the DTED CD-ROM

A complete Microsoft MS-DOS file specification for a DTED cell on CD reader device D, located at 12°E and 48°N would be represented as shown:

D:/DTED/E0120000/N480000.DT1

Each cell file contains a 3508-byte series of descriptive ASCII headers followed by a latitude-dependent number of records. The number of records varies with latitude because the longitude post spacing of DTED increases with latitude to compensate for the convergence of the meridians at the poles. Each record

contains a series of 1201 two-byte binary elevation values for one column of longitude. On some computers, such as IBM-compatible PCs, it is necessary to swap the bytes in the elevation values. (Byte order used for binary data storage varies from computer to computer.) These records are completely described by the DMA product specifications for DTED and the information booklet packaged with the CD-ROMs.

The "C" function DATA (listed in Appendix A) illustrates a general-purpose reader providing random access to elevations for any geographic position on the CD-ROM, while supporting rapid sequential access by buffering one longitudinal column of elevations. To take full advantage of the speed offered by this reader, calls should be ordered by column and file. (One read is performed upon longitudinal column change. One file open and two reads are performed upon file change.)

## 4.0 Evaluation System Description

For sample applications, development, and testing, NORDA used an IBM-compatible PC (Zenith 248) with Enhanced Graphics Adapter and an Amdek Laser-drive CD-ROM reader with Hitachi Device Driver. The CD-ROM reader had an access time of 0.8 seconds. Programming languages used were Microsoft FORTRAN 3.2 and Microsoft "C" 5.0.

## 5.0 Sample Applications and Results

The "C" programs described in the following paragraphs are listed in Appendix A. The programs were written in order to assess the correctness of the digital representation on the CD-ROM, the general usefulness of the product, and to provide programming examples for product users. CONGEO plots a screen map of any geographic area contained on a single CD-ROM. CONSAMP plots a screen map of a file produced using program SAMPLE. CONTOUR plots a screen map of the southwest portion of a single DTED cell at full resolution. DATA is a function providing random geographic access to any point on the CD-ROM. SAMPLE creates a sampled file of any geographic area contained on a single CD-ROM. The FORTRAN 3.2 programs are not listed because this FORTRAN 77 subset implementation is not considered adequate for these applications due to the following deficiencies:

- lack of character substring function
- lack of graphics interface
- inability to open files in other than the default directory.

Later versions of Microsoft FORTRAN and FORTRAN 77 implementations generally do not have these deficiencies.

## 5.1 Application 1: Subsampling of a CD-ROM Coverage Area to a Disk File

The Microsoft FORTRAN 4.0 program provided by Mr. Jere Cadoret of the DMA Systems Center was most useful as an example of a DTED reader. Significant changes, however, were required to run under FORTRAN 3.2. File name restrictions prevented random access across directories. Access using FORTRAN was rather slow. It appeared that a small internal buffer caused a large read to be translated into a series of smaller reads, each taking a 0.8 second access time. Direct access to columns of data was awkward since the size of the DTED file header is not a multiple of the elevation data record size. It is strongly recommended that Microsoft FORTRAN users of this product upgrade to level 4.0. The "C" language proved to be more convenient and nearly twice as fast.

## 5.2 Application 2: Terrain Relief Map of DTED from CD-ROM

A simple pixel-based algorithm was implemented to render the terrain with color-coded Tanaka contours. The Tanaka contouring technique<sup>5</sup> uses a simulated direction of illumination to shade the contour lines. As the contour interval goes to zero, all pixels are turned on and the map becomes color filled with shaded relief. Programs were coded in FORTRAN 3.2 and "C" 5.0 to display a section of a DTED file at the file resolution of about 100 m. A program was written in "C" to display any rectangular region within a CD-ROM by subsampling the CD-ROM DTED files. The FORTRAN effort was limited by lack of a graphics interface (one had to be written in assembly language and was not completely debugged). Microsoft FORTRAN 4.0 and above are adequate and capable of using the "C" graphics interface.

Figures 1-6 were produced by running the "C" programs, then photographing from the Zenith 248 screen. On these figures the elevation data is color coded, with red being the highest elevation. The shading reveals the fine texture in the terrain data. Simulated illumination is from the north. CD-ROM numbers refer to the proposed DTED CD-ROM Index.

Figure 1 (CD-ROM #9, ONCs D-1, D-2, D-3) and Figure 2 (CD-ROM #15, ONCs E-1, E-2, E-3) were produced using program CONGEO to subsample and display the entire CD-ROM areas. The areas were stretched to the 640 × 350 screen resolution. Considerable distortion resulted, but the maximum data resolution possible on the evaluation system hardware was provided. Each took about 2 hours to plot, since the entire CD-ROM was sampled. To shorten display time, sampled files can be created using program SAMPLE; these can be plotted using program CONSAMP and will produce the same images in about 2 minutes. On Figure 2, the absence of the west coast of Denmark should be noted. This omission points out





Figure 1. Prototype DTED CD-ROM #9.



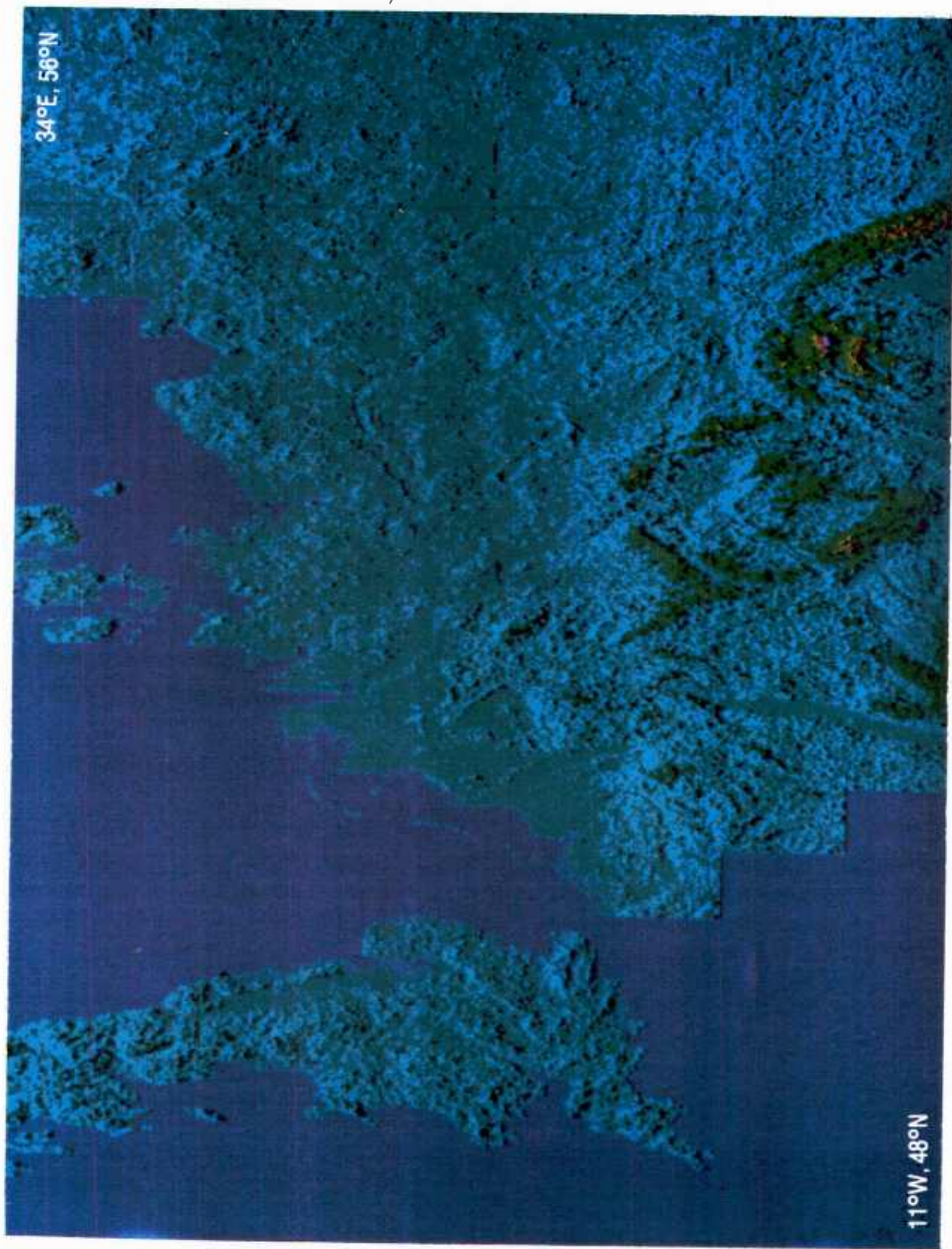


Figure 2. Prototype DTED CD-ROM #15.

a discrepancy in the indicated data coverage. DTED cells for 8°E, 54°N and 8°E, 55°N were indicated to be present on the Location Diagram but were not present on the CD-ROM.

Figures 3 and 4 show the lower part of the one-degree cell at 7°E and 61°N using program CONTOUR at the DTED Level 1 resolution of about 100 m. Figure 3 uses a contour interval of 250 m, and plots in 3.5 minutes from CD-ROM or in 1 minute from the CD-ROM file copied to hard disk. (MS-DOS copy takes 30 seconds for files at this latitude). Figure 4 shows the same file at a contour interval of 0 m, resulting in the color-filled, shaded relief. Plotting time for Figure 4 was 6.5 minutes from CD-ROM and 3.5 minutes from hard disk.

Figure 5 (Southern Norway) and Figure 6 (Eastern Europe) show an intermediate level of resolution of about 1 km. The areas shown are 4° of latitude by 8° of longitude.

## 6.0 Evaluators' Responses to Questionnaire

DMA's list of evaluators is included as Appendix B. This list was developed through responses to a call for evaluators in the *DMA Newsletter*. Collated responses to DMA's evaluation questionnaire are included as Appendix C. DMA distributed an additional questionnaire, which is included as Appendix D.

### 6.1 User Information

Most potential Navy users can accept the CD-ROM media in place of magnetic tape, but some do not have CD-ROM readers. Tape distribution may be phased out after the CD-ROM distribution is in place, and all users can read them.

Most users will be using both batch and interactive processing methods.

Table 1 lists the computer systems expected to use DTED from CD-ROM as drives and software drivers become available.

Table 1. List of the computer systems expected to use DTED from CD-ROM as drives and software drivers become available.

MICROVAX III	Intergraph Interview 360
IBM PC Compatible (Zenith 248)	Sun 3-160, 3-280
VAX 11-785	Silicon Graphics IRIS
VAX 11-750	AN/SYQ (V)
VAX 8550	COMPAQ 386/30 PC
Tektronix 4325, 4336, 4301	CDC Cyber 875

## 6.2 Packaging and Security

Most users considered the information booklet at least adequate, but the information on ISO 9660 drivers needs to be updated, since these are now available.

Most users considered the location diagram to be sufficiently detailed, but some want it to be larger, with the bounds of the covered area labeled, and with more latitude and longitude labels to avoid counting squares. Figure 7 is a copy of one of these location diagrams.

Most users felt the CD-ROM label contained enough information. Both the label and the package need a prominent CD-ROM number to help keep them together when several are in use.

No user had a problem with the physical security requirement.

### 6.3 Maintenance

Most users prefer annual updates. Some feel that a new CD-ROM should be produced when significant updates occur.

Users who do not have CD-ROM readers will continue to require updates on magnetic tape.

### 6.4 Ancillary Data

Only one user reported a requirement for the gazetteers.

### 6.5 CD-ROM Index

Most users considered the organization into 85 CD-ROM areas acceptable; however the Tactical Air Mission Planning System (TAMPS) evaluation (Appendix E) strongly recommends a breakdown by even multiples of 6° in latitude and longitude.

## 7.0 Conclusions

- The CD-ROM is an excellent distribution media for DTED in terms of cost and weight.

- Since CD-ROM reader devices are not widely available for mainframe computer systems, some users will continue to require magnetic tape distribution. A common solution is by networking a Personal Computer with a CD-ROM reader to the mainframe.

- Byte swapping of the 2-byte elevation records was required for the IBM PC evaluation system used at NORDA.

- The organization of the CD-ROM areas around Operational Navigation Charts does not suit the Navy's needs.

- Minor discrepancies in the data content (missing cells) were noted.

- Different record lengths for the header and data records made direct access using the FORTRAN language awkward.

- The organization of the 1° DTED cells into directories as separate files precluded random access



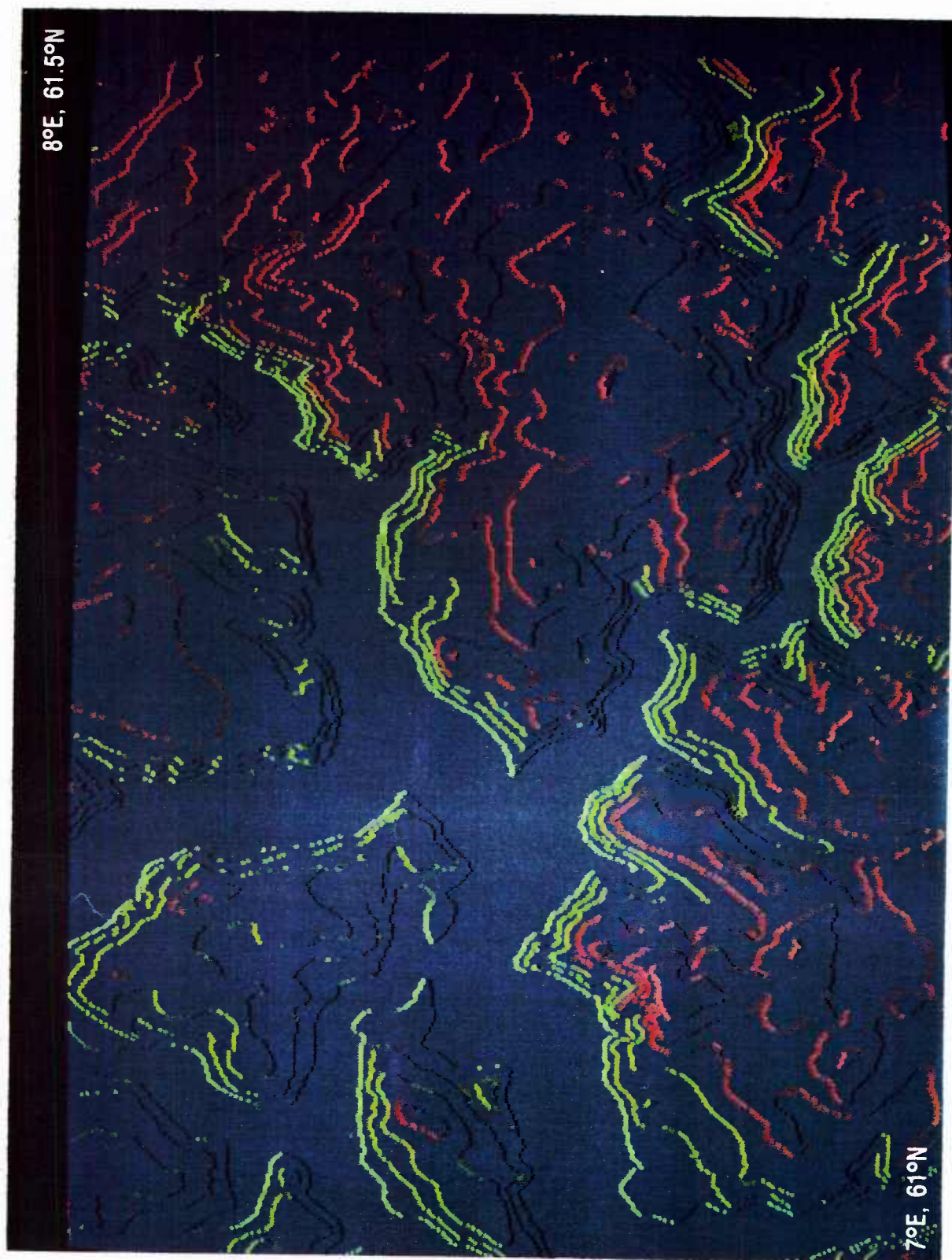


Figure 3. 250-m shaded contour of partial DTED cell.

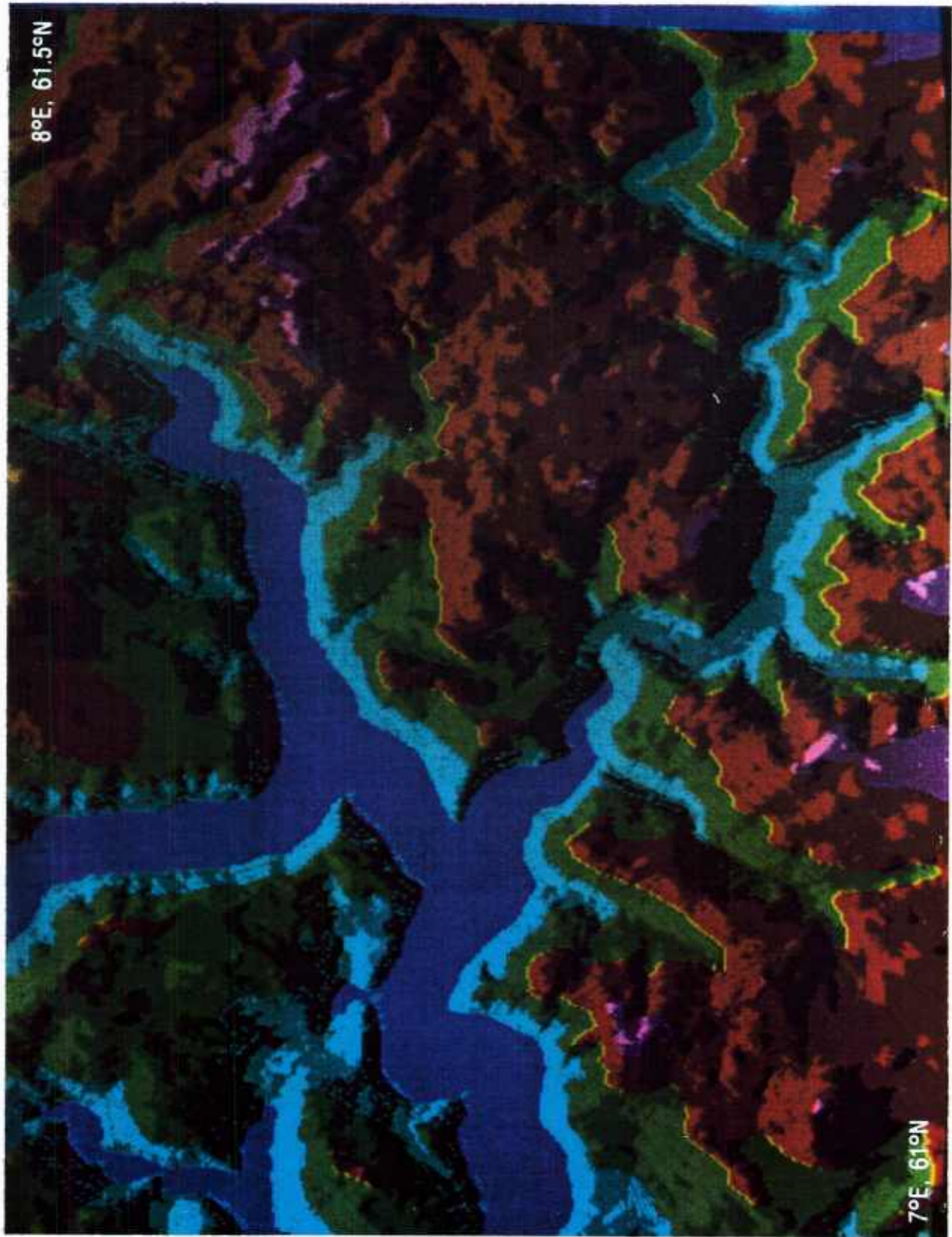


Figure 4. Color shaded relief of partial DTED cell.



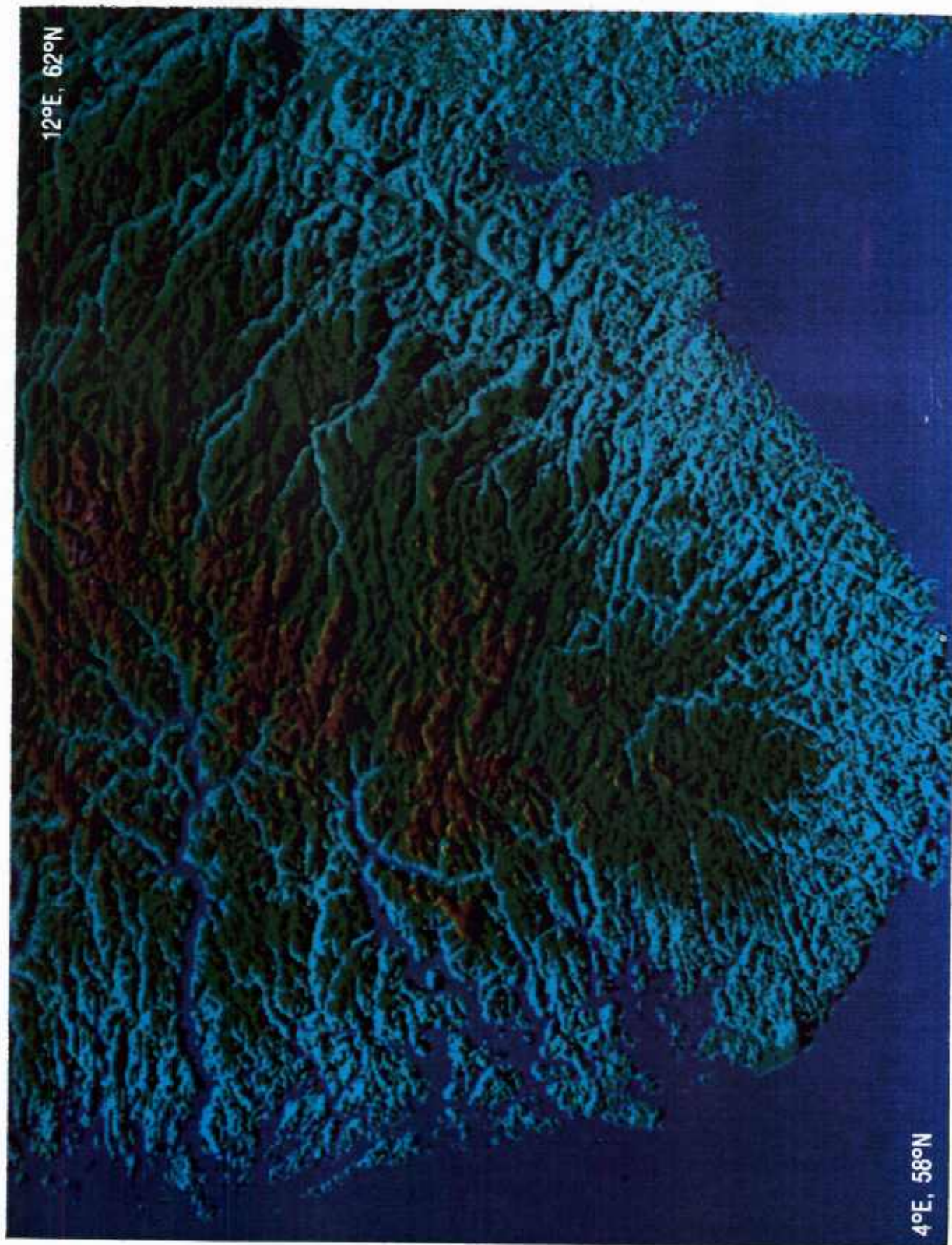


Figure 5. Southern Norway from CD-ROM #9.





Figure 6. Eastern Europe from CD-ROM #15.

## LOCATION DIAGRAM

Geographic Coverage of ONC Areas:  
48°00'N to 56°00'N  
11°00'W to 34°00'E

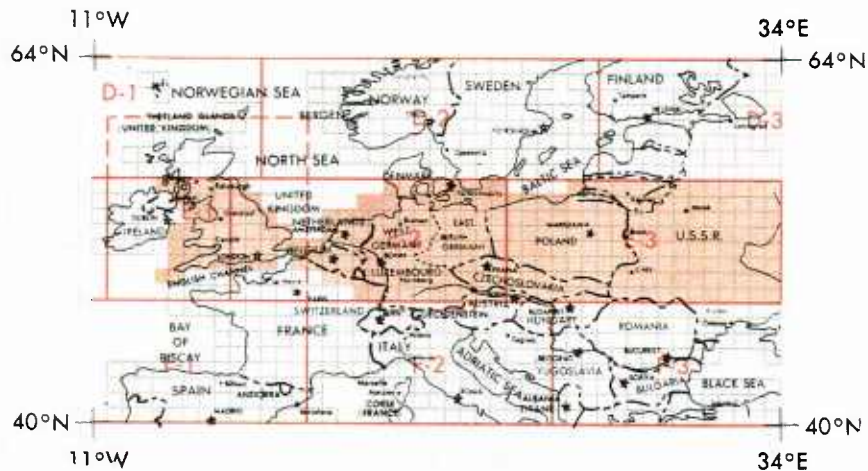


Figure 7.

across files under the Microsoft FORTRAN 3.2 language but was possible under Microsoft "C" 5.1. and would be possible with Microsoft FORTRAN 4.0 and above.

- The Location Diagram supplied with the CD-ROMs is not adequate and needs to be reworked.
- The software supplied with the evaluation package was not adequate to perform a thorough evaluation.

## 8.0 Recommendations

### 8.1 Recommendations Not Affecting the DTED File Format

1. Reorganize the CD-ROM index into areas bordered by integer multiples of 6° in latitude and longitude. This reorganization would make the algorithmic determination of CD-ROM number from geographic position simpler. It would facilitate the use of CD-ROM as a worldwide, on-line data base. It would directly support the TAMPs application and would result in a less cluttered, easier-to-read index. The following are the desired characteristics; six-degree multiple boundaries, preferably square; full CD-ROM; and geographic and political features intact.

2. Insure that the location diagram accurately reflects the contents of the CD-ROM. Differences were noted on CD-ROM #9.

3. Enlarge the Location Diagram in the CD-ROM case. Use more latitude and longitude labels to reduce "counting the squares." This would be more readily accomplished if the areas were more square. Another solution would be to supplement it with a paper chart for each CD-ROM showing the covered areas in some sort of terrain relief, possibly similar to Figures 1 and 2,

but with lighter shades, a 1° labeled geographic grid, and selected place names plotted from the gazetteer. This method could also serve to automate the production of the location diagram, avoid discrepancies due to human error, and provide users with an overview of the topography.

4. Provide updates as significant changes occur via restamped CD-ROM. Any other update system would be awkward for an interactive user.

5. Place a prominent CD-ROM number on both the CD-ROM and case.

### 8.2 Recommendations Affecting the DTED File Format

While evaluation of the DTED file format is beyond the scope of this evaluation of the CD-ROM as a distribution medium, this may be a good time to reconsider the file format in light of the possibilities offered by the CD-ROM technology.

1. Include the maximum and minimum elevations in a DTED cell in the cell header to facilitate graphical applications where elevations are scaled into colors.

2. Make the length of the cell headers a multiple of the data record length to facilitate direct access using fixed record length. The elevation record length is 2414 bytes. The cell header length is now 3508 bytes. The header length should either be shortened to 2414 bytes or extended to 4828 bytes.

3. Consider data compression techniques to put more data on each CD-ROM.

4. A common Navy platform for reading the CD-ROM is the IBM-compatible PC, which requires byte swapping of the binary elevation records. This byte swapping should be done before creating the CD-ROM.



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5. Consider possible reorganization to support rapid retrieval of data at various levels of resolution. An example would be a low-resolution grid containing elevation averages, as well as pointers to higher resolution grid files. These higher resolution grid cells could contain pointers to even higher resolution data. The CD-ROM technology offers many possibilities to exploit.

## 9.0 References

1. Chief of Naval Operations (1986). CNO Ltr Ser 098R/64353525.

2. Commander, Naval Oceanography Command (1983). Ltr Ser 952/3U349699.

3. Gebhardt, Kim and Susan Carter (1989). *Navy Requirements for Digital Mapping, Charting, and Geodesy Data*. Naval Ocean Research and Development Activity, Stennis Space Center, MS, NORDA Report (in preparation).

4. Defense Mapping Agency (1986). *Product Specifications for Digital Terrain Elevation Data*. Second Edition, Defense Mapping Agency Aerospace Center, St. Louis, MO, April.

5. Langran, Gail (1984). *Map Design for Computer Processing: Literature Review and DMA Product Critique*. Naval Ocean Research and Development Activity, Stennis Space Center, MS, NORDA Report 72, December.



## **Appendix A**

### **“C” Program Listings**

---

```

/*
PROGRAM CONGEO - a pixel based contour algorithm          18-NOV-1988
Uses Microsoft C5.1 on IBM PC with EGA.
Produces the following displays of any rectangular area contained within
a single Digital Terrain Elevation Data Compact Disk:
COLOR CONTOUR (contour interval > 0, shading threshold large),
TANAKA SHADED CONTOUR (contour interval > 0, shading threshold small),
COLOR FILLED CONTOUR (contour interval = 0, shading threshold large),
COLOR SHADED RELIEF (contour interval=0, shading threshold small)

```

User inputs:

```

backcol- short- background and data out of range color
datmin,datmax- short- data outside this range will not be
                plotted. Hues will be scaled to this range.
conint- short- contour interval in meters. Since the same code
                is used for contouring and filling if cint=0,
                a color filled map results.
shade_threshold- short- the amount of elevation change in
                adjacent grid points that will result in the pixel
                being shaded light or dark. If very large, no shading
                will result. A negative value moves the illumination
                from the North to the South.
rlonw,rlone,rlats,rlatn- double- geographic bounds of desired map

```

Routines called: Microsoft C 5.0 run time library

```

data- short- returns an elevation from the CD-ROM for a geographic
position.

```

Algorithm:

```

for each x
  for each y
    if data is within desired range
      if contour interval not 0, compute contour number
      if contour interval is 0 or contour number has changed
        from last point
        scale the data value into a hue
        compare slope against shade_threshold to get shade
        compute color number from hue and shade
        color the pixel

```

Limitations: The simple algorithm used results in missing pixels on vertical contour lines.

Author: Jerry Landrum, Naval Ocean Research and Development Activity  
 Code 351, Stennis Space Center, Ms. 39522 phone (601) 688-4613  
 AV 485-4613

```

*/
#include <stdio.h>
#include <stdlib.h>
#include <graph.h>
#define XMAXSC 640
#define YMAXSC 350

```

```

void main(void);

```

```

/*
Until a better way is found to set the palette, dark grey is used as
the dark shade of all the hues.
color map:   cyan   green   red   magenta
             d m l   d m l   d m l   d m l
                                           d=dark

```

m=medium  
l=light

\*/

```

        | | | | | | | | | |
short pal[12]={8,3,11,8,2,10,8,4,12,8,5,13};

void main(void)
{
    short data(double a, double b);
    short len,i;
    short x=0,y=0;
    char line[80];
    char ok='n';
    short dat;
    float cscale;
    short color,hue,diff,datlas,shade,range,backcol;
    short datmin,datmax,shade_threshold;
    short conint,ic,iclast;
    short firstc=0;
    short nshade=3;
    short nhue=4;
    short xmax=XMAXSC;
    short ymax=YMAXSC;
    double rlonw,rlone,rlats,rlatn,rlon,rlat,rlonin,rlatin,geoinc;

/* get user input */
    input;;
    printf("Program PIXCON, hit RETURN to use default value in ()\n\n");
    printf("Enter background color number (9)\n");
    gets(line);
    if(sscanf(line,"%d",&backcol)<1) backcol=9;
    printf("Enter minimum data value? (1)\n");
    gets(line);
    if(sscanf(line,"%d",&datmin)<1) datmin=1;
    printf("Enter maximum data value? (2000)\n");
    gets(line);
    if(sscanf(line,"%d",&datmax)<1) datmax=2000;
    printf("Enter contour interval? (0)\n");
    gets(line);
    if(sscanf(line,"%d",&conint)<1) conint=0;
    printf("Enter shading threshold? (10)\n");
    gets(line);
    if(sscanf(line,"%d",&shade_threshold)<1) shade_threshold=10;
    printf("Enter geographic limits of area, west,east,south,north-real?");
    printf("      ( 41. 43. 56. 58. )");
    gets(line);
    if(sscanf(line,"%lf %lf %lf %lf",&rlonw,&rlone,&rlats,&rlatn)<4)
        {rlonw=41.;rlone=43.;rlats=56.;rlatn=58.;}
    range=datmax-datmin;
    cscale= (float)nhue/(float)range;
    rlonin= (rlone-rlonw)/(double)XMAXSC;
    rlatin= (rlatn-rlats)/(double)YMAXSC;
    if(rlonin>rlatin) geoinc=rlonin;
    else geoinc=rlatin;
    printf("WESN: %lf %lf %lf %lf\n",rlonw,rlone,rlats,rlatn);
    printf("rlonin,rlatin: %lf %lf\n",rlonin,rlatin);
    printf("Any changes? (n)");
    scanf("%s",ok);

```

```
    if(ok=='y') goto input;
/* one dummy call to function data so it prompts for CD drive before graphics m
    dat=data(rlonw,rlds);
/* set up terminal*/
    if (_setvideomode(_ERESCOLOR)==0)
    {
        printf("Graphics mode not available.\n");
        exit(-1);
    }
/* clear the screen */
    _setcolor(backcol);
    _rectangle(_GFILLINTERIOR,0,0,640,350);
/* outer loop in x, x corresponds to pixel position and data column */
    for(rlon=rlonw;rlon<=rlone;rlon=rlon+geoinc)
    {
        y=0;
        for(rlat=rlds;rlat<=rlatn;rlat=rlat+geoinc)
        {
            dat=data(rlon,rlat);
            /* printf("rlon,rlat,dat: %lf %lf %d\n",rlon,rlat,dat);*/
/* test for desired data range */
            if((dat>datmin) && (dat<datmax))
            {
                if(conint !=0) ic=dat/conint;
                if((conint==0)|| (ic!=iclast))
                {
/* compute hue, shade, and color */
                    hue=(dat-datmin+conint/2)*cscale;
                    diff=dat-datlas;
                    shade=1;
                    if(diff<=-shade_threshold) shade=2;
                    if(diff>shade_threshold) shade=0;
                    color=firstc+shade+hue*nshade;
                    iclast=ic;
/* color one pixel */
                    _setcolor(pal[color]);
                    _setpixel(x,350-y);
                    /* printf("x,y,color: %d %d %d\n",x,y,color);*/
                }
                datlas=dat;
                y++;
            } /* end of y loop */
            x++;
        } /* end of x loop */
/* end the program upon keyboard action */
        while(!kbhit()); /* Strike any key to continue */
        _setvideomode(_DEFAULTMODE);
    }
```

```
/*
PROGRAM CONSAMP - a pixel based contour algorith. Input file of DTED produce
using program SAMPLE. This program does not read the DTED distributio
format.
```

Uses Microsoft C5.1 on IBM PC with EGA.

Produces the following displays of Digital Terrain Elevation Data  
read from a Compact Disk Read Only Memory file:

COLOR CONTOUR (contour interval > 0, shading threshold large),  
TANAKA SHADED CONTOUR (contour interval > 0, shading threshold small),  
COLOR FILLED CONTOUR (contour interval = 0, shading threshold large),  
COLOR SHADED RELIEF (contour interval=0, shading threshold small)

User inputs:

backcol- short- background and data out of range color  
datmin,datmax- short- data outside this range will not be  
plotted. Hues will be scaled to this range.  
conint- short- contour interval in meters. Since the same code  
is used for contouring and filling if cint=0,  
a color filled map results.  
shade\_threshold- short- the amount of elevation change in  
adjacent grid points that will result in the pixel  
being shaded light or dark. If very large, no shading  
will result. Simulated light from the north.  
file- char- name of sampled elevation file produced by program  
SAMPLE.

Algorithm:

```
for each x
  for each y
    if data is within desired range
      if contour interval not 0, compute contour number
      if contour interval is 0 or contour number has changed
        from last point
        scale the data value into a hue
        compare slope against shade_threshold to get shade
        compute color number from hue and shade
        color the pixel
```

Limitations: The simple algorithm used results in missing pixels on  
vertical contour lines.

Author: Jerry Landrum, Naval Ocean Research and Development Activity  
Code 351, Stennis Space Center, Ms. 39522 phone (601) 688-4613  
AV 485-4613

```
*/
#include <stdio.h>
#include <stdlib.h>
#include <graph.h>
#define XMAXSC 640
#define YMAXSC 350
```

```
void main(void);
```

```
/* Until a better way is found to set the palette, dark grey is used as
the dark shade of all the hues.
```

```
color map:   cyan   green   red     magenta
              d m l   d m l   d m l   d m l
```

```
d=dark
m=medium
l=light
```



```

      | | | | | | | |
*/
    short pal[12]={8,3,11,8,2,10,8,4,12,8,5,13};
    char file[30];
void main(void)
{
    short len,i;
    short x,y;
    FILE *fin;
    char line[80];
    float header[8];
/* header[0]=rlonw, [1]=rlone, [2]=rlats, [3]=rlatn,
   [4]=lon spacing [5]=lat spacing [6]=width of grid [7]=height of grid*,
    short data[YMAXSC];
    short dat;
    float cscale;
    short color,hue,diff,datlas,shade,range,backcol;
    short datmin,datmax,shade_threshold;
    short conint,ic,iclast;
    short firstc=0;
    short nshade=3;
    short nhue=4;
    short iw,ih;
    short xmax=XMAXSC;
    short ymax=YMAXSC;

/* get user input */
    printf("Program PIXCON, hit RETURN to use default value in ()\n\n");
    printf("Enter background color number (9)\n");
        gets(line);
        if(sscanf(line,"%d",&backcol)<1) backcol=9;
    printf("Enter minimum data value? (1)\n");
        gets(line);
        if(sscanf(line,"%d",&datmin)<1) datmin=1;
    printf("Enter maximum data value? (2000)\n");
        gets(line);
        if(sscanf(line,"%d",&datmax)<1) datmax=2000;
    printf("Enter contour interval? (0)\n");
        gets(line);
        if(sscanf(line,"%d",&conint)<1) conint=0;
    printf("Enter shading threshold? (10)\n");
        gets(line);
        if(sscanf(line,"%d",&shade_threshold)<1) shade_threshold=10;
    printf("Enter DTED sampled file spec? (%s)\n",file);
        gets(line);
        printf("len= %d",strlen(line));
        if(strlen(line) > 1) sscanf(line,"%s",file);
    while ((fin = fopen(file,"rb"))==NULL){
        printf("Error opening file: %s\n",file);
        printf("Enter another file spec?");
        scanf("%s",file);}
    len = fread(header,sizeof(float),8,fin);

/* extract the file width and height */
    ih=header[7];
    iw=header[6];
    if(ih<YMAXSC) ymax=ih;

```

```
        if(iw<XMAXSC) xmax=iw;
/* set up terminal*/
        if (_setvideomode(_ERESCOLOR)==0)
        {
            printf("Graphics mode not available.\n");
            exit(-1);
        }
/* clear the screen */
        _setcolor(backcol);
        _rectangle(_GFILLINTERIOR,0,0,640,350);
        range=datmax-datmin;
        cscale= (float)nhue/(float)range;
/* outer loop in x, x corresponds to pixel position and data column */
        for(x=0;x<=xmax;x++)
        {
/* read one column of DTED data */
            len=fread(data,2,ih,fin);
/* inner loop in y, y corresponds to pixel position and data row */
            for(y=0;y<=ymax;y++)
            {
                dat=data[y];
/* test for desired data range */
                if((dat>datmin) && (dat<datmax))
                {
                    if(conint !=0) ic=dat/conint;
                    if((conint==0)|| (ic!=iclast))
                    {
/* compute hue, shade, and color */
                        hue=(dat-datmin+conint/2)*cscale;
                        diff=dat-datlas;
                        shade=1;
                        if(diff<-shade_threshold) shade=2;
                        if(diff>shade_threshold) shade=0;
                        color=firstc+shade+hue*nshade;
                        iclast=ic;
/* color one pixel */
                        _setcolor(pal[color]);
                        _setpixel(x,350-y);
                    }
                    else iclast=-1;
                    datlas=dat;
                } /* end of y loop */
            } /* end of x loop */
            fclose(fin);
/* end the program upon keyboard action */
            while(!kbhit()); /* Strike any key to continue */
            _setvideomode(_DEFAULTMODE);
        }
    }
```

```
/*
PROGRAM CONTOUR - a pixel based contour algorithm
Uses Microsoft C5.1 on IBM PC with EGA.
Produces the following displays of Digital Terrain Elevation Data
    read from a Compact Disk Read Only Memory file:
    COLOR CONTOUR (contour interval > 0, shading threshold large),
    TANAKA SHADED CONTOUR (contour interval > 0, shading threshold small),
    COLOR FILLED CONTOUR (contour interval = 0, shading threshold large),
    COLOR SHADED RELIEF (contour interval=0, shading threshold small)
```

User inputs:

```
    backcol- short- background and data out of range color
    datmin,datmax- short- data outside this range will not be
                    plotted. Hues will be scaled to this range.
    conint- short- contour interval in meters. Since the same code
              is used for contouring and filling if cint=0,
              a color filled map results.
    shade_threshold- short- the amount of elevation change in
                        adjacent grid points that will result in the pixel
                        being shaded light or dark. If very large, no shading
                        will result. A negative value moves the illumination
                        from the North to the South.
    file- char- file specification of DTED
            elevation file, either on CD-ROM or copied to hard
            disk.(runs faster from hard disk)
```

Algorithm:

```
    for each x
        for each y
            if data is within desired range
                if contour interval not 0, compute contour number
                if contour interval is 0 or contour number has changed
                    from last point
                    scale the data value into a hue
                    compare slope against shade_threshold to get shade
                    compute color number from hue and shade
                    color the pixel
```

Limitations: The simple algorithm used results in missing pixels on vertical contour lines.

Author: Jerry Landrum, Naval Ocean Research and Development Activity  
Code 351, Stennis Space Center, Ms. 39522 phone (601) 688-4613  
AV 485-4613

```
*/
#include <stdio.h>
#include <stdlib.h>
#include <graph.h>
#define XMAXSC 640
#define YMAXSC 350
```

```
void main(void);
```

```
/*    Until a better way is found to set the palette, dark grey is used as
    the dark shade of all the hues.
```

```
    color map:    cyan    green    red    magenta
                  d m l    d m l    d m l    d m l
```

```
    d=dark
    m=medium
    l=light
```

```

*/
    short pal[12]={8,3,11,8,2,10,8,4,12,8,5,13};

    char file[ ]="D:\\DTED\\E0080000\\N610000.DT1";
void main(void)
{
    short len,i;
    short x,y;
    FILE *fin;
    char line[80];
    unsigned char header[3508];
    short data[1207];
    short dat;
    float cscale;
    short color,hue,diff,datlss,shade,range,backcol;
    short datmin,datmax,shade_threshold;
    short conint,ic,iclast;
    short firstc=0;
    short nshade=3;
    short nhue=4;
    char iws[4],ihs[4];
    short iw,ih;
    short xmax=XMAXSC;
    short ymax=YMAXSC;

/* get user input */
    printf("Program PIXCON, hit RETURN to use default value in ()\n\n");
    printf("Enter background color number (9)\n");
    gets(line);
    if(sscanf(line,"%d",&backcol)<1) backcol=9;
    printf("Enter minimum data value? (1)\n");
    gets(line);
    if(sscanf(line,"%d",&datmin)<1) datmin=1;
    printf("Enter maximum data value? (2000)\n");
    gets(line);
    if(sscanf(line,"%d",&datmax)<1) datmax=2000;
    printf("Enter contour interval? (0)\n");
    gets(line);
    if(sscanf(line,"%d",&conint)<1) conint=0;
    printf("Enter shading threshold? (10)\n");
    gets(line);
    if(sscanf(line,"%d",&shade_threshold)<1) shade_threshold=10;
    printf("Enter DTED file spec? (%s)\n",file);
    gets(line);
    printf("len= %d",strlen(line));
    if(strlen(line) > 1) sscanf(line,"%s",file);
    while ((fin = fopen(file,"rb"))==NULL){
        printf("Error opening file: %s\n",file);
        printf("Enter another file spec?");
        scanf("%s",file);}
    len = fread(header,1,3508,fin);
    printf("%i %s\n", len,header);
/* extract the file width and height */
    for(i=0;i<4;i++) ihs[i]=header[i+441];
    for(i=0;i<4;i++) iws[i]=header[i+445];
    ih=atoi(ihs);
    iw=atoi(iws);
    if(ih<YMAXSC) ymax=ih;

```

```

        if(iw<XMAXSC) xmax=iw;
/* set up terminal*/
        if (_setvideomode(_ERESCOLOR)==0)
        {
            printf("Graphics mode not available.\n");
            exit(-1);
        }
/* clear the screen */
        _setcolor(backcol);
        _rectangle(_G_FILLINTERIOR,0,0,640,350);
        range=datmax-datmin;
        cscale= (float)nhue/(float)range;
/* outer loop in x, x corresponds to pixel position and data column */
        for(x=0;x<=xmax;x++)
        {
/* read one column of DTED data */
            len=fread(data,2,1207,fin);
/* must swap bytes on IBM */
            swab((char *)data,(char *)data,sizeof(data));
/* inner loop in y, y corresponds to pixel position and data row */
            for(y=0;y<=ymax;y++)
            {
                dat=data[y+4];
/* test for desired data range */
                if((dat>datmin) && (dat<datmax))
                {
                    if(conint !=0) ic=dat/conint;
                    if((conint==0)|| (ic!=iclast))
                    {
/* compute hue, shade, and color */
                        hue=(dat-datmin+conint/2)*cscale;
                        diff=dat-datlas;
                        shade=1;
                        if(diff<-shade_threshold) shade=2;
                        if(diff>shade_threshold) shade=0;
                        color=firstc+shade+hue*nshade;
                        iclast=ic;
/* color one pixel */
                        _setcolor(pal[color]);
                        _setpixel(x,350-y);
                    }
                }
                datlas=dat;
            } /* end of y loop */
        } /* end of x loop */
        fclose(fin);
/* end the program upon keyboard action */
        while(!kbhit()); /* Strike any key to continue */
        _setvideomode(_DEFAULTMODE);
    }

```



/\* FUNCTION DATA Microsoft C 5.0

Random access retrieval of Digital Terrain Elevation Data from  
Compact Disk- Read Only Memory

inputs- double rlon- longitude in real degrees, positive for East,  
negative for West.  
double rlat- latitude in read degrees, positive for North,  
negative for South.

output- short data- elevation in meters read from CD-ROM. If no  
data available at the position, a value of -9999 is returned.

method- buffers one longitude column of data, thus it is much faster  
if called for points in vertical order.

algorithm- If desired point not in the currently open DTED file  
construct new file spec and open.  
If desired point not currently in the column buffer,  
read the desired column.  
Extract the desired point from the column buffer.

by- Jerry Landrum, NORDA DMAP, AV 485-4613

```
*/
#include <stdio.h>
#include <stdlib.h>
short data(double rlon,double rlat)
{
FILE *fin;
static char file[30]="D:\\DTED\\E00000000\\N000000.DT1";
/*          01 23456 789012345 678901234567890 */
    short dat[1201];
    static long firste=3516;
    static long lencol=2414;
    long recnum;
    long i,lon,lat,lonsec,latsec,latindex;
    static long lonspc,latsec,column,lastcolumn=-9999;
    static int lastlon=9999,lastlat=9999;
    static short nofile=0,nodata=-9999;
    static int first=1;
    char lonc[4],latc[3],drive[1];
    long seek,len;
    double rlond,rlatd;
/* bias the lon with 360 and lat with 180 - this makes things easier
since the addressing within a file is from the lower left corner. */
    rlond=rlon+360.;
    rlatd=rlat+180.;
/* extract integer degrees to construct file spec, and fractional part
in seconds to compute position of elevation in the file. */
    lon=(int)rlond;
    lonsec=(rlond-(double)lon)*3600;
    lat=(int)rlatd;
    latsec=(rlatd-(double)lat)*3600;
/* if lat or lon of lower left corner has changed, must construct a file spec,
close the currently open file and try to open the new one. */
    if((lon!=lastlon) || (lat!=lastlat))
    {
        lastlon=lon;
        lastlat=lat;
    }
}
```

```

        for(i=10;i<13;i++) file[i]='0';
        for(i=19;i<21;i++) file[i]='0';
        itoa(abs(lon-360),lonc,10);
        itoa(abs(lat-180),latc,10);
        for(i=0;i<strlen(lonc);i++) file[12-strlen(lonc)+i]=lonc[i];
        for(i=0;i<strlen(latc);i++) file[20-strlen(latc)+i]=latc[i];
        if(lon<360) file[8]='W';
            else file[8]='E';
        if(lat<180) file[17]='S';
            else file[17]='N';
/*  prompt for CD-ROM device letter on first call only */
        if(first==1)      {first=0;
                           printf("Enter CD-ROM drive letter(1 char)?");
                           scanf("%s",drive);
                           file[0]=drive[0];
        printf("file: %s",file);}
        else fclose(fin);
        if((fin=fopen(file,"rb"))==NULL)
            nofile=1; /* flag indicates file could not be opened*/
        else
        {
            nofile=0; /* flat indicates file successfully opened*/
/*  read and decode the lon and lat spacing (lonspc,latspc) from file header */
            fseek(fin,(long) 100,SEEK_SET);
            fscanf(fin,"%4ld%4ld",&lonspc,&latspc);
            lonspc=lonspc/10;
            latspc=latspc/10;
            lastcolumn=-999;
        }
/*  if the needed file could not be opened, return the nodata value */
        if (nofile==1) return nodata;
/*  if the longitude column changed from the last call,
must read a column of DTED*/
        column=lonsec/lonspc;
        if(column!=lastcolumn)
/*  recnum is the byte offset to the desired column of data */
        {
            recnum= firste + column*lencol;
            seek=fseek(fin,recnum,SEEK_SET);
/*  read one column of data */
            len=fread(dat,sizeof(short),1201,fin);
/*  on IBM must swap the bytes */
            swab( (char*)dat,(char*)dat,sizeof(dat));
/*  save longitude for test on next call */
            lastcolumn=column;
        }
/*  latindex is the index into the column of data for the desired latitude */
        latindex=latsec/latspc;
/*  return the desired elevation */
        return dat[latindex];
}

```

```
/* PROGRAM SAMPLE Microsoft C 5.0
   Produces a rectangular grid file on disk by regular sampling of DTED
   from CD-ROM.

   inputs(from terminal):
       outfil- char- output file spec
       iw,ih- short- desired output grid width and height
       rlonw,rlone,rlats,rlatn- double- west,east,south,north limits
       of desired area.

   routines called- Microsoft C 5.0 run time library
       data- short- returns a data value for a geographic
       position from the DTED CD-ROM.

   method: compute sampling increment (geoinc) from inputs, retrieve
       the data column by column and write to output file.

   by: Jerry Landrum, NORDA DMAP, AV 485-4613.
*/
#include <stdio.h>
#include <stdlib.h>
#define XMAX 640
#define YMAX 350

void main(void);

void main(void)
{
    short data(double a, double b);
    double rlonw,rlone,rlats,rlatn,rlatin,rlonin,rlon,rlat;
    short iw,ih,ix,iy;
    static float header[8];
/* buffer for one column of output data */
    static datout[YMAX];
    FILE *fout;
    static char outfil[30];
/* get user input */
    printf("Enter output file spec?");
        scanf("%s",outfil);
    printf("Enter desired output file size, x and y?\n");
        scanf("%d %d",&iw,&ih);
        if(ih>YMAX){
            printf("File too big, reset YMAX in program SAMPLE");
            exit(-1);}
    printf("Enter geographic limits(WESN)?\n");
        scanf("%lf %lf %lf %lf",&rlonw,&rlone,&rlats,&rlatn);
/* rlonin is sampling increment in degrees lon */
    rlonin=(rlone-rlonw)/(double)iw;
/* rlatin is sampling increment in degrees lat */
    rlatin=(rlatn-rlats)/(double)ih;
/* form the output file header, open output file, and write out header */
    header[0]=rlonw;
    header[1]=rlone;
    header[2]=rlats;
    header[3]=rlatn;
    header[4]=rlatin;
    header[5]=rlonin;
    header[6]=(float)iw;
```

```
    header[7]=(float)ih;
    printf("%f %f %f %f %f %f %f %f\n",header[0],header[1],header[2],header
    fout=fopen(outfil,"wb");
    fwrite((char *)header,sizeof(float),8,fout);
    rlon=rлонw;
/*  begin loop for columns left to right */
    for(ix=0;ix<iw;ix++)
    {
        rlat=rлатс;
/*  begin loop for one column bottom to top */
        for(iy=0;iy<ih;iy++)
        {
/*  function data returns one elevation for any point on the CD-ROM */
            datout[iy]=data(rlон,rlat);
            rlat=rlat+rlatin;
        }
/*  end of one column, write it to the output file */
        fwrite(datout,sizeof(short),ih,fout);
        rлон=rлон+rлонin;
    }
/*  end of column loop, close output file */
    fclose(fout);
}
```

## **Appendix B**

### **Evaluation Team Members**

---

Evaluator	Serial Number	Autovon	Commerical
CDR Chuck Miller, III NAVAIRSYSCOM Code 526W Washington, DC 20361	00068	222-3449	202 692-3449
Mr. Alan May Naval Avionics Center Mail Stop Branch 824 6000 E. 21st St. Indianapolis, IN 46219	00066	369-3587	317 353-3587
LCDR Richard Daley PMRF Code 7320A KEUAHA, HI 96752	00065		808 335-4416
Mrs. Susan Alderson NOSC Code 421 San Diego, CA 92152-5000	00064		
Ms. Cathy Fazen NAVELEX PNSY 76/6 Code 0215 Philadelphia, PA 19112-5075	00069	443-5530	215 897-5530
Mr. Victor Fickes PRB Associates 47 Airport View Dr. Hollywood, MD 20636	00063		301 373-2360
Ms. Virginia Foster Mr. Bob Lesperance Naval Flight Information Group Naval Air Facility, Washington Washington, DC 20396-5137	00062		301 981-5745
MSGT Roger Livingston 485 EIG/EIEUC Griffiss AFB, NY 13441-6348	00061	587-4466	315 330-4466



Evaluator	Serial Number	Autovon	Commerical
Mr. John M. Quinn NAVOCEANO Code 6M SSC, MS 39522-5001	00060	485-5828	601 688-5828
Gary N. Richard NSWC Code N22 Dahlgren, VA 22448	00059		703 663-4229
Mr. Sam Smith NSWC Code K12 Dahlgren, VA 22448	00058	249-8159	703 663-8159
Mr. Matthew T. South PMTC Code 5021 Bldg. 333 Pt. Mugu, CA 93042-5000	00057	351-7976	805 989-7976
Mr. A. Duane Gomez NOSC Code 433 San Diego, CA 92152	00056	553-3577	619 553-3577
Mr. Don LeMoyné NSWC Code F31 Dahlgren, VA 22448	00053	249-7966	703 663-7966
Mr. Bill Taylor Commander, NOSC Code 722 San Diego, CA 92152-5000	00067		
Ms. Mary Clawson CNO (OP-096) Attn: 961CN U.S. Naval Observatory 34th & Massachusetts Ave. NW Washington, DC 20392-1800	00052		202 653-1610
Mr. Allan D. Crane PRB Associates, Inc. 47 Airport View Dr. Hollywood, MD 20636	00055		301 373-2360

Evaluator	Serial Number	Autovon	Commerical
Maura Lohrenz NORDA Code 351 Stennis Space Center, MS 39529-5004	00051	485-4611	601 688-4611
Jim Braud NORDA Code 351 Stennis Space Center, MS 39529-5004	00054	485-4422	601 688-4422
Jerry Landrum NORDA Code 351 Stennis Space Center, MS 39529-5004	00050	485-4613	601 688-4613

## **Appendix C**

### **Collated Responses**

---

**Digital Terrain Elevation Data  
Compact Disc-Read Only Memory (DTED CD-ROM)  
Engineering Prototype Evaluation Form  
Control Number \_\_\_\_\_**

**I. General:**

DMA has prepared two engineering prototypes of DTED produced on Compact Disc-Read Only Memory (CD-ROM). These engineering prototype DTED CD-ROMs are part of this evaluation package. Also enclosed in the package is a copy of the Product Specifications for DTED. The data on these Engineering Prototype discs conforms to DTED specifications with the exceptions noted in the CD-ROM Information Booklet. We suggest you carefully examine and familiarize yourself with the DTED Specifications and the exceptions noted in the CD-ROM Information Booklet prior to initiating your evaluation.

As a condition of acceptance of these DTED CD-ROMs, you are required to complete this form and forward it to DMASC/WG in the enclosed envelope. Your comments and suggestions will be combined with those Evaluation Forms we receive from other users and will form the basis for finalizing our CD-ROM design. These evaluation forms must be mailed no later than 18 November 1988 for your comments and suggestions to be considered for inclusion in our final DTED CD-ROM product design and production planning.

Enclosed in the evaluation package are 2 DTED CD-ROM indexes. Please annotate one of the copies with any changes or modifications you feel would be an improvement to the world-wide index. Send the annotated copy along with your evaluation form in the return envelope.

The following information in Sections II-VII is requested to help us provide a product that will support our users' needs. Please provide **UNCLASSIFIED** detailed answers where appropriate. Use additional sheets if necessary.

**II. User Information:**

1. DMA is considering no longer distributing DTED on magnetic tapes. The data will be provided on CD-ROMs only. Do you consider this

Acceptable 7

Unacceptable (Please Explain) 2

---

---

---

---

---

---

2. We consider our users to fall into two categories: Batch and Interactive. Batch users are users who transfer the DTED data from the CD-ROM to magnetic mass storage, then access the data from mass storage in a mini- or mainframe-computer environment. Interactive users are users who access the data directly from the CD-ROM in a micro- or mini-computer environment. Using these definitions, do you consider yourself a Batch User, Interactive User, or Both?

Batch User 3

Interactive User \_\_\_\_\_

Both 6

3. Please describe the computer system(s) you plan on using to exploit the DTED

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4. How many copies of each DTED CD-ROM do you require? \_\_\_\_\_

5. Your Name \_\_\_\_\_

Title \_\_\_\_\_

Address \_\_\_\_\_

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Telephone Number Commercial ( ) AUTOVON



### III. Packaging and Security:

DMA plans are to provide future CD-ROMs with packaging and labeling similar to that of this Engineering Prototype. Each CD-ROM would come in the plastic case, and will include a location diagram on the back of the case, and an information booklet that slides in and out of the front of the case. The CD-ROM will be labeled with text indicating the contents of the disc, date mastered, classification and/or restrictions, stock numbers and other pertinent information.

1. Do you consider the information in the Information Booklet:

More than adequate 4

Adequate 2

Less than Adequate (Please Explain) 1

Insufficient (Please Explain) 2

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2. The Location Diagram located on the back panel of the plastic case gives a graphic portrayal of the area contained on the CD-ROM.

Do you consider the detail of the Location Diagram

Too detailed 1

Sufficiently detailed 7

Lacking detail (Please Explain) 1

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3. Does the CD-ROM label contain:

More than enough information 1

Enough information 7

Not enough information (Please Explain) 1

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4. Holders of DMA digital products are required to protect their holdings against misuse or loss. As a minimum, DMA recommends to users that whenever digital products are not under supervision of authorized persons, the data will be secured in a container or vault (e.g. 4-drawer safe) that provides physical evidence of unauthorized tampering or forced entry.

Does this requirement for a secure container or vault pose a problem?

No 9

Yes (Please Explain)       

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#### IV. Maintenance:

DMA is considering providing periodic updates of DTED on CD-ROMs. These updates will be distributed and function similar to the DMA Chart Updating Manual (CHUM) and Notice To Mariner (NTM) maintenance system. For example, a maintenance CD-ROM will contain any new or modified cells produced since the issue of the original disc.

1. For your application, do you consider these updates necessary?

Yes 8

No 1

2. For your needs, should these updates occur:

Quarterly 1

Semi-Annually 1

Annually 4

Other (Specify) 3

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3. Between the periodic maintenance CD-ROMs, DMA is considering no longer distributing DTED updates on magnetic tapes. For your application, would this be an impact?

No 8

Yes (Please Explain) 1

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## V. Ancillary Data:

This question references the ancillary data that will accompany the DTED data.

1. The disc also includes gazetteers. Gazetteers give the user an opportunity to quickly define geo-coordinates for certain geographic features that have geographic names. The geo-coordinates can be used to extract DTED information for the feature and vicinity. For your application, is the gazetteer data:

Desired 1

Required 2

Not Required 4

No Opinion 2

Should not be on the disc \_\_\_\_\_

## VI. CD-ROM Index:

This question references the enclosed proposed DTED CD-ROM index. There are 85 areas that have been defined. Each disc will contain all filled 1 degree cells in the area. Efforts were made to define the index of the areas by ONCs and geographically.

1. Do you consider the breakdown of the index into the 85 areas:

Acceptable 8

Not Acceptable (Please Explain) 1

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**VII. Suggestions and/or Comments:**

Please use this area to express any concerns you may have that have not been addressed in this questionnaire.

[illegible]



## **Appendix D**

### **DMAP Questionnaire**

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Additional Questions for DMAP  
Digital Terrain Elevation Data  
Compact Disk-Read Only Memory (DTED CD-ROM)

1. Do you have a hardware system for reading the CD-ROM?

If so:

What kind?

Were you able to read it?

If not:

Are you planning to get one?

What kind?

2. Do you have a graphics system suitable for display of DTED?

If so:

Were you able to display it?

What graphics system?

What graphics software?

What type of display? (contour, wireframe, shaded relief)

If not:

Are you planning to get one?

What kind?

3. Do you now have software that uses DTED?

If so:

Were you able to interface the CD-ROM?

What computer language is your software?

What is your preferred language for supplied readers and demos?

If not:

Are you planning to develop software to use DTED?

Please describe your plans.

## **Appendix E**

### **Evaluation of Digital Terrain Elevation Data (DTED) on CD-ROM Tactical Air Mission Planning System (TAMPS) Application (Draft)**

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# EVALUATION OF DIGITAL TERRAIN ELEVATION DATA ON CD-ROM TACTICAL AIR MISSION PLANNING SYSTEM APPLICATION

## 1. BACKGROUND

The Tactical Air Mission Planning System (TAMPS) currently utilizes the services of McDonnell-Douglas for the reformatting of Digital Terrain Elevation Data (DTED) cells that are initially distributed by the Defense Mapping Agency (DMA) on magnetic tape media. In the reformatting process, the 1-degree DTED cells are divided into as many as 64 subcells, each of which contain an 8-bit elevation matrix that is dimensioned as either (151,151) (151,101), depending upon the latitude. Scale factors are included with each subcell that allow for the 8-bit values to be expanded to the original 16-bit values with minimum loss of precision.

The reformatting process produces large files that contain all DTED and that are bounded by even multiples of 6 degrees of latitude and longitude. These files are called "load modules" and if fully populated, they can contain the equivalent of 36 DTED 1-degree cells. A single load module can represent nearly 52 million points for areas between 48 and -48 degrees latitude. Each subcell is written out as a fixed-length, 22884-byte record; when loaded, from tape to disk, it can be read by direct access. The load modules are numbered by four-digit integers, starting at number 0001, the southwest corner of which is at -90 latitude and -180 longitude. The numbering system results in 30-latitude bands of 60 load modules per band.

The load modules are distributed to the 84 planned TAMPS workstations via magnetic tape. Each tape typically contains 4 to 5 load modules, but may contain as many as 10. The size of the load module may depend on several factors, such as the latitude, percentage of completed cells, and the number of subcells that are over water at constant altitude.

With the 8-bit values that are used in the subcells, there is a possibility of 256 separate data levels. Of these, only 252 are actually used to store the elevation data. Although it is only speculation on my part, the additional four levels are likely used to support color overlays on the graphic display system that probably support 8-bit planes of color graphics. The 8-bit elevation data values are therefore used to support rapid rendering of DTED by the graphic display system. It is unclear at this point, however, how the simultaneous display of multiple subcells is handled. Since the scale factors will vary between subcells, there is a need to somehow normalize the elevations by applying the scale factors to the data prior to display. This could result in significant overhead during run-time and negate the advantage of using 8-bit data to directly feed the display processor when multiple subcells are displayed.



Perhaps an equally important reason that the DTED is stored as 8-bit values is the fact that the original TAMPS was severely limited in mass storage. The reformatted load modules require only half the storage that is required by the original 16-bit DTED data. This allowed for twice as much elevation data to be directly accessible as would have been allowed if 16-bit data values were used. The I/O transfer rate from disk to main memory is likewise doubled due to the use of 8-bit values.

## 2. DTED ON CD-ROM

The prototype of DTED on CD-ROM is distributed on two CD-ROM disks using the High Sierra standard format. All cells are on the World Geodetic System 1984 (WGS 84). The first disk contains 341 one-degree cells of Level 1 DTED in ONC areas D-1, D-2, and D-3. The second disk contains 275 one-degree cells in areas E-1, E-2, and E-3. This is the equivalent of between 7 and 9 load modules before reformatting. The DTED is written in fixed length data records and can be read directly as random access files. The directory structure and file-naming scheme allows for easy generation of the path and file name for any of the 1-degree cells.

Currently the High Sierra format is not supported by Digital Equipment Corporation (DEC). DEC will support the proposed actual distribution format ISO-9660 on the MicroVAX II and MicroVAX III using a Q-bus controller. These are the only DEC machines that currently support the addition of a CD-ROM reader as a peripheral. The only hardware/software configuration available at the Naval Ocean Research and Development Activity (NORDA) for the evaluation of a High Sierra formatted DTED CD-ROM consists of a Zenith 248, 8-MHz, AT compatible with floating point processor connected to an Amdek Laserdrive-1 CD-ROM reader.

## 3. OPTIONS

There are several options that could be considered as a means of utilizing the CD-ROM distribution of DTED data by the TAMPS. For all of the options considered, TAMPS would benefit greatly if instead of using the ONC area as determining boundaries of data to be included on the distribution CD-ROM, even multiples of 6 degrees latitude and longitude were used. This would conform to the load modules' boundaries and would allow for complete load modules to be processed directly from CD-ROM without having to change CD-ROM disks. This is the strongest recommendation that should be made as a result of the TAMPS evaluation and should not result in a major impact on DMA at this early stage.

Option 1: Utilize DTED data directly from CD-ROM in its original distribution format.

To increase processing speed (CD-ROM is relatively slow compared to current magnetic disk technology). DTED data would be directly loaded from CD-ROM onto magnetic disk as required for mission planning areas.

The advantages of this option would be the elimination of the reformatting process completely. Data could be updated in more timely manner if direct distribution were done by DMA. Space and weight requirements would be reduced for CD-ROM distribution media versus magnetic tape.

The disadvantages would involve a possible major rewrite of existing software. If 8-bit data is truly needed by the graphic subsystem, the conversion from 16-bit to 8-bit data values must take place in real time with a degradation of graphic performance. Disk-to-memory transfer rate and available magnetic storage for on-line DTED storage is halved.

Option 2: Conversion or reformatting of CD-ROM DTED to TAMPs format at the TAMPs site as needed for mission planning.

Instead of the time required to mount and search magnetic tape sequentially for the load modules needed, the reformatting could take place directly on-line from the CD-ROM reader to the magnetic disk. This is the option that is presently being evaluated at NORDA.

Normally four load modules are required to be loaded for a mission planning session. These load modules require between 15 and 35 minutes to load from the magnetic tape. If the reformatting process could be completed in an equivalent amount of time, then all of the advantages of the direct distribution of DTED on CD-ROM by DMA could be gained without any performance loss or software rewrites.

The NORDA Digital Mapping, Charting, and Geodesy (MC&G) Analysis Program (DMAP) has developed software to perform the conversion on the PC configuration described above. The output listing that is included with this report reveals that the conversion from CD-ROM of load module 1415 required 1 hour and 30 minutes using this low-end configuration. The worst-case scenario (full load module located between -48 and 48 degrees latitude) currently would require about 2 hours and 16 minutes to convert using a PC.

This conversion process was also simulated using the VAX 8700 that is part of the Mass Data Formatting Facility (MDFF) located at NORDA. Preliminary results revealed an approximate 4 minutes and 15 seconds of CPU time and about 6 minutes of wall clock time required for the reformatting of load module 1535 (only half the size of a worst-case load module) using this configuration. Four load modules of this size were reformatted simultaneously allowing overlap of CPU and I/O

time. The total wall clock time required to complete all four jobs was slightly over 20 minutes. This would indicate a worst-case clock time of 40 minutes for four full-coverage load modules at the lower latitudes using a VAX 8700.

According to DEC officials, the VAX 8700 performance is about 5 to 6.6 times that of a MicroVAX II. The VAXstation 3200, which is based on a MicroVAX III CPU, has a performance measurement that is 2.4 to 4.2 times that of a VAXstation GPX, which is based on a MicroVAX II. From these numbers, one could cautiously derive that the worst-case reformatting process for four full-load modules could take between 60 and 80 minutes of wall clock time. As indicated by these numbers, performance measurements can vary drastically according to mixes of instructions and I/O. It is unknown what type of measurements are used to generate these figures. The reformatting process is mostly compute bound and the actual transformation has been modified to utilize strictly integer arithmetic in order to speed up the processing. True indications of performance should be obtained through benchmarking prior to basing decisions on performance.

These preliminary results reveal that there could be a moderate loss of throughput if the reformatting or loading of the DTED is on the critical path (all other steps stopped while data are loaded) for mission planning.

Option 3: Reformatting of DTED at the TAMPS workstation as CD-ROM is received directly from DMA.

This may involve more training and bookkeeping for the TAMPS administrator. There would be no savings in space or weight because magnetic tape would be used as the primary storage media. All other elements of mission planning would remain the same. There would be a minimum software effort for NORDA to complete the conversion software.

Option 4: Use of NORDA MDFF as a reformatting facility using CD-ROM.

Hardware and software already exist. Estimate annual cost is \$30K plus supplies (magnetic tapes, any hardware modifications, etc.).

Option 5: Use of CD-ROM at McDonnell-Douglas reformatting facility.

This should be more efficient than current tape methods because of the volume of data that can be directly accessed on a single CD-ROM cartridge.



# Distribution List

Asst Secretary of the Navy  
(Research, Engineering & Systems)  
Navy Department  
Washington DC 20350-1000

Chief of Naval Operations  
Navy Department (OP-02)  
Washington DC 20350-2000

Chief of Naval Operations  
Navy Department (OP-71)  
Washington DC 20350-2000

Director  
National Ocean Data Center  
WSC1 Room 103  
6001 Executive Blvd.  
Attn: G. W. Withee  
Rockville MD 20852

Chief of Naval Operations  
Navy Department (OP-987)  
Washington DC 20350-2000

Oceanographer of the Navy  
Chief of Naval Operations  
Attn: OP-096  
U.S. Naval Observatory  
34th & Mass Ave., NW  
Washington DC 20390-1800

Commander  
Naval Air Development Center  
Warminster PA 18974-5000

Commanding Officer  
Naval Coastal Systems Center  
Panama City FL 32407-5000

Commander  
Space & Naval Warfare Sys Com  
Washington DC 20363-5100

Commanding Officer  
Naval Environmental Prediction  
Research Facility  
Monterey CA 93943-5006

Commander  
Naval Facilities Eng Command  
Naval Facilities Eng Command Headquarters  
200 Stovall St.  
Alexandria VA 22332-2300

Commanding Officer  
Naval Ocean R&D Activity  
Attn: Code 100  
Stennis Space Center MS 39529-5004

Commanding Officer  
Naval Ocean R&D Activity  
Attn: Code 125L (13)  
Stennis Space Center MS 39529-5004

Commanding Officer  
Naval Ocean R&D Activity  
Attn: Code 125P (1)  
Stennis Space Center MS 39529-5004

Commanding Officer  
Naval Ocean R&D Activity  
Attn: Code 105  
Stennis Space Center MS 39529-5004

Commanding Officer  
Naval Ocean R&D Activity  
Attn: Code 115  
Stennis Space Center MS 39529-5004

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Naval Ocean R&D Activity  
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Stennis Space Center MS 39529-5004

Commanding Officer  
Naval Ocean R&D Activity  
Attn: Code 300  
Stennis Space Center MS 39529-5004

Commanding Officer  
Naval Research Laboratory  
Washington DC 20375

Commander  
Naval Oceanography Command  
Stennis Space Center MS 39529-5000

Commanding Officer  
Fleet Numerical Oceanography Center  
Monterey CA 93943-5005

Commanding Officer  
Naval Oceanographic Office  
Stennis Space Center MS 39522-5001

Commander  
Naval Ocean Systems Center  
San Diego CA 92152-5000

Commanding Officer  
ONR Branch Office  
Box 39  
FPO New York NY 09510-0700

Commander  
David W. Taylor Naval Research Center  
Bethesda MD 20084-5000

Commander  
Naval Surface Weapons Center  
Dahlgren VA 22448-5000

Commanding Officer  
Naval Underwater Systems Center  
Newport RI 02841-5047

Superintendent  
Naval Postgraduate School  
Monterey CA 93943

Director of Navy Laboratories  
Rm 1062, Crystal Plaza Bldg 5  
Department of the Navy  
Washington DC 20360

Officer in Charge  
New London Laboratory  
Naval Underwater Sys Cen Det  
New London CT 06320

Director  
Office of Naval Research  
Attn: Code 10  
800 N. Quincy St.  
Arlington VA 22217-5000

Director  
Woods Hole Oceanographic Inst  
P.O. Box 32  
Woods Hole MA 02543

University of California  
Scripps Institute of Oceanography  
P.O. Box 6049  
San Diego CA 92106

Officer in Charge  
Naval Surface Weapons Center Det  
White Oak Laboratory  
10901 New Hampshire Ave.  
Attn: Library  
Silver Spring MD 20903-5000

Commanding Officer  
Fleet Anti-Sub Warfare Training Center, Atlantic  
Naval Station  
Norfolk VA 23511-6495



Brooke Farquhar  
NORDA Liaison Office  
Crystal Plaza #5, Room 802  
2211 Jefferson Davis Hwy.  
Arlington VA 22202-5000

Director  
Defense Mapping Agency Sys Cen  
Attn: SGWN  
12100 Sunset Hill Rd. #200  
Reston VA 22090-3207

NORDA  
Code 125 EX  
Stennis Space Center MS 39529-5004  
(Unlimited only)

Director  
Office of Naval Technology  
Attn: Dr. P. Selwyn, Code 20  
800 N. Quincy St.  
Arlington VA 22217-5000

Director  
Office of Naval Technology  
Attn: Dr. C. V. Votaw, Code 234  
800 N. Quincy St.  
Arlington VA 22217-5000

Director  
Office of Naval Technology  
Attn: Dr. M. Briscoe, Code 228  
800 N. Quincy St.  
Arlington VA 22217-5000

Director  
Office of Naval Research  
Attn: Dr. E. Hartwig, Code 112  
800 N. Quincy St.  
Arlington VA 22217-5000

Director  
Office of Naval Research  
Attn: Code 12  
800 N. Quincy St.  
Arlington VA 22217-5000

Director  
Office of Naval Research  
Attn: Dr. E. Silva, Code 10D/10P  
800 N. Quincy St.  
Arlington VA 22217-5000

Chief of Naval Operations  
Navy Department (OP-0962X)  
Attn: Mr. R. Feden  
Washington DC 20350-2000

Commander  
Naval Sea Systems Command  
Naval Sea Systems Command Headquarters  
Washington DC 20362-5101

Commanding Officer  
Naval Civil Engineering Laboratory  
Port Hueneme CA 93043

Commander  
Naval Air Systems Command  
Naval Air Systems Command Headquarters  
Washington DC 20361-0001

Pennsylvania State University  
Applied Research Laboratory  
P.O. Box 30  
State College PA 16801

University of Texas at Austin  
Applied Research Laboratories  
P.O. Box 8029  
Austin TX 78713-8029

Johns Hopkins University  
Applied Physics Laboratory  
Johns Hopkins Rd.  
Laurel MD 20707

University of Washington  
Applied Physics Laboratory  
1013 Northeast 40th St.  
Seattle WA 98105

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